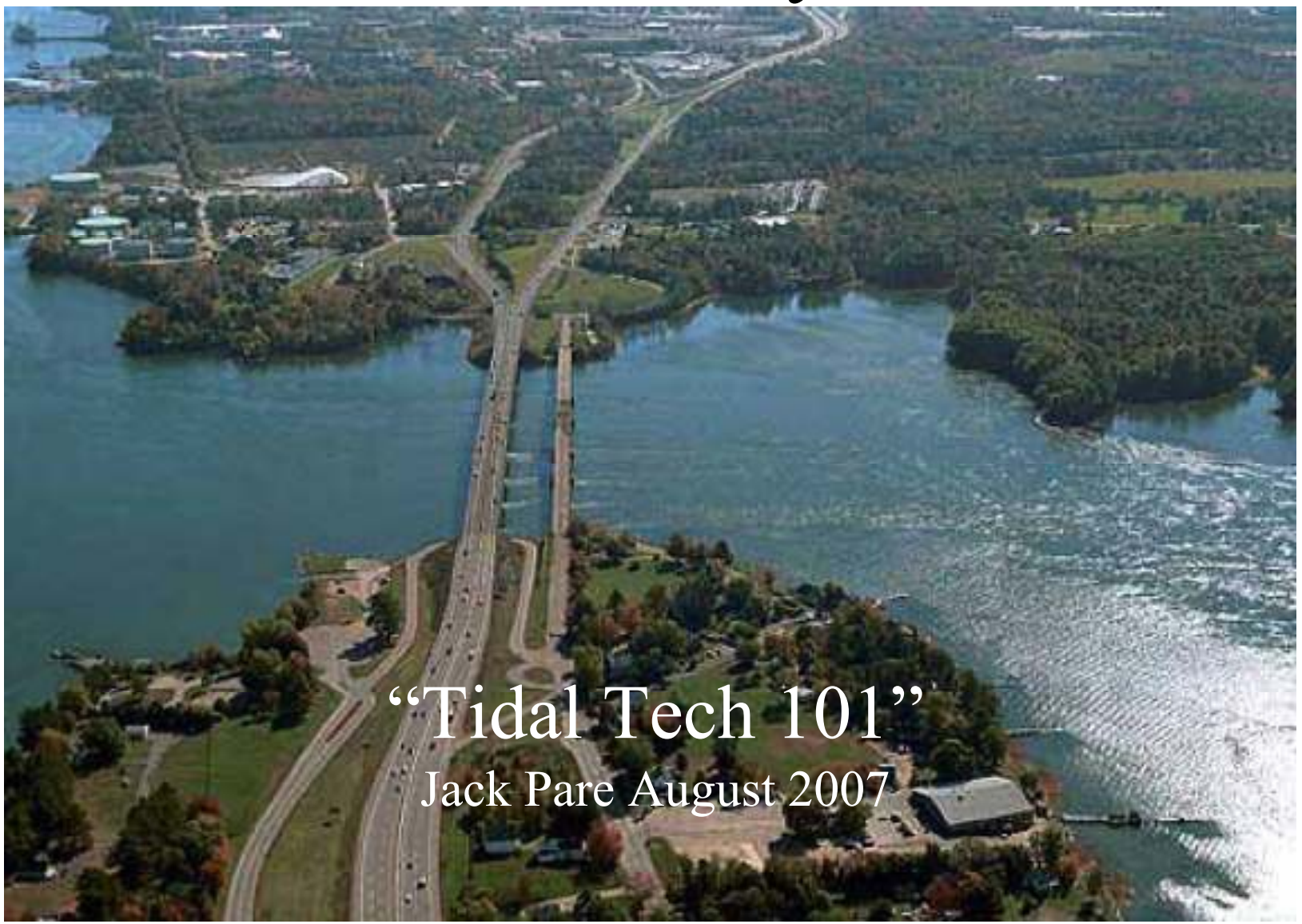
NH Tidal Power Study Commission



NH Electricity Prices/Costs

- In 2005, NH had the 3rd highest electricity prices in the US, behind Hawaii and New York.
- In 2006, NH prices held steady, while other rose. NH is now 6th - behind Hawaii, Connecticut, Massachusetts, New York and Rhode Island.
- Cost of energy generation sources (e.g. coal, oil, gas) is a major contributor
  – all must be imported

from US Dept of Energy - Electric Power Monthly January 12, 2007
http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html
State-by-state rank values computed from data

NH Electricity Prices/Costs

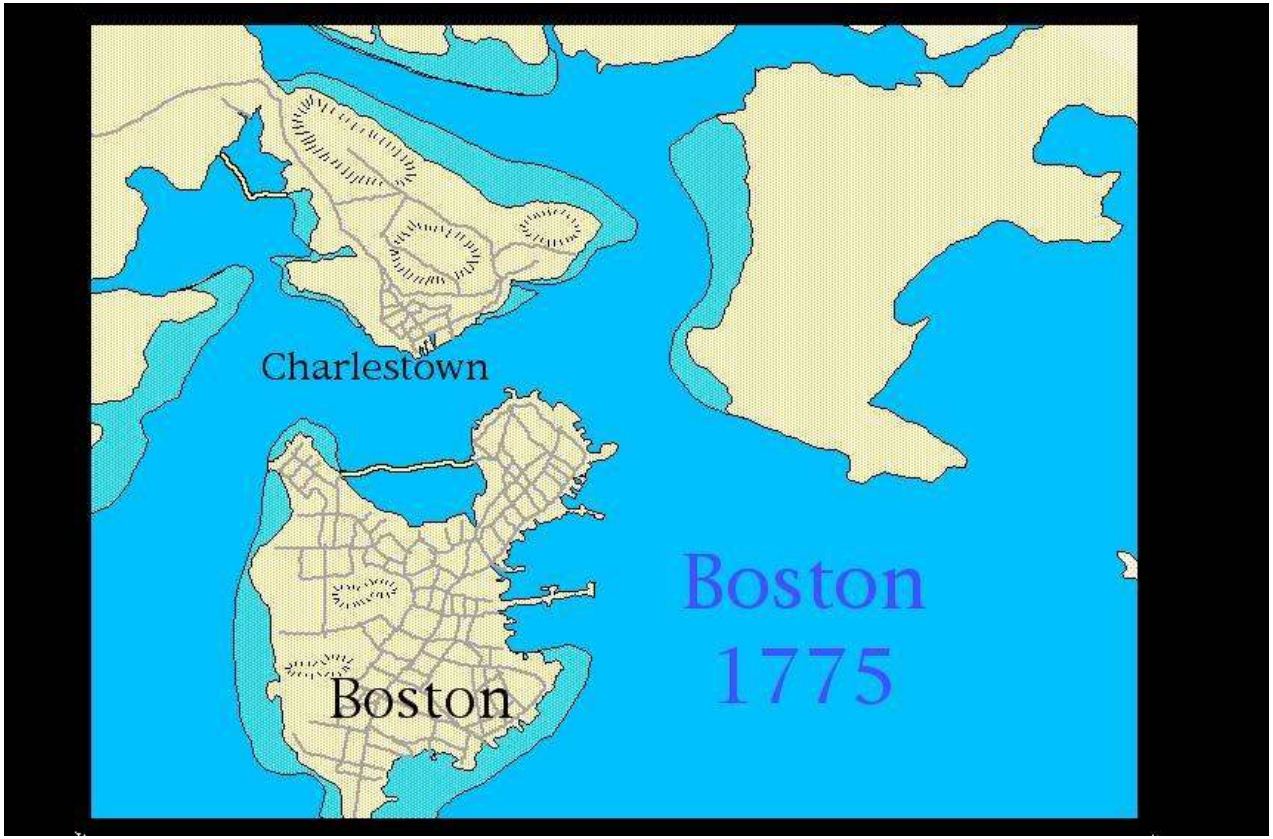
National average cost of Electricity
8.83 cents per kilowatt hour

NH average cost of Electricity
13.53 cents per kilowatt hour

from US Dept of Energy - Electric Power Monthly January 12, 2007
www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

- These electric rates permit Tidal Power to be cost competitive in NH – even before Renewable Energy Certificates are applied.

Three Types of Tidal Power:
Dams, Free Current, Choke Point



Dams (Barrages)

Since the 11th century in England and France.

1775 Boston map shows a tide mill dam (now Causeway Street).

Operation: Let high tide into millpond
Wait for low tide
Release water through grist mill's water wheel

Tidal Barrage classic example

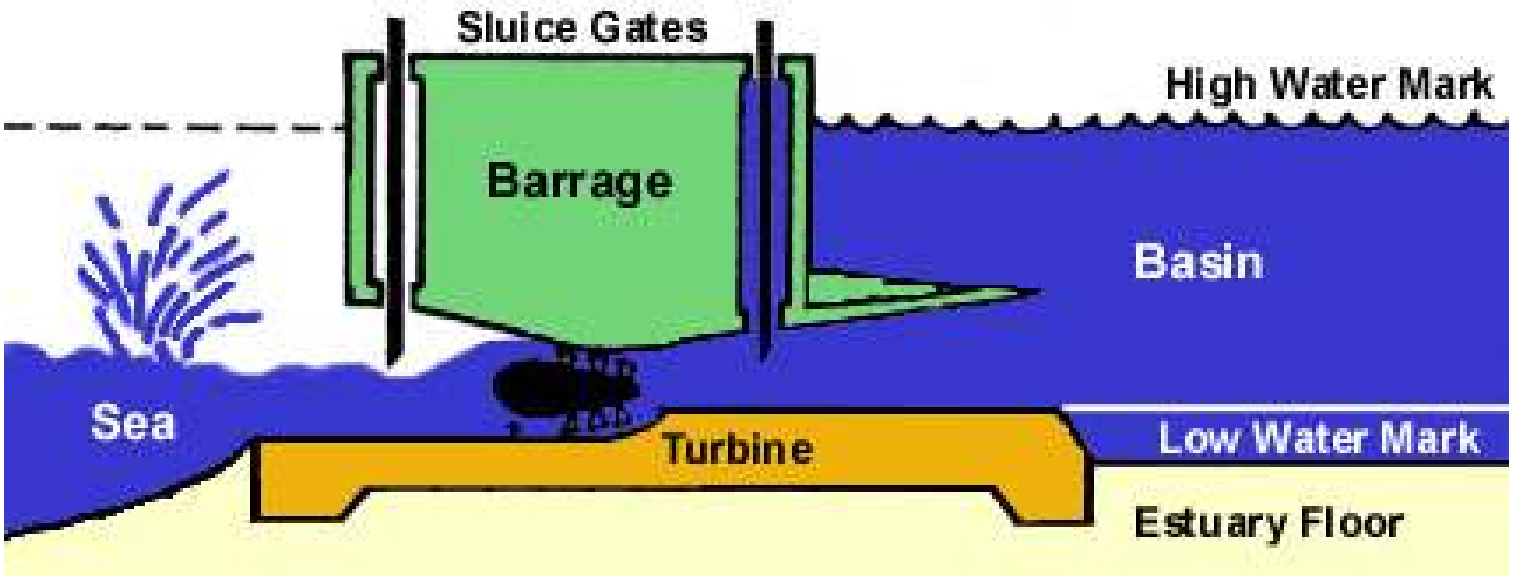
The La Rance dam
mid ‘60s, St. Malo, France
2,362 feet long
bulb turbines to right
4-lane highway on dam
lock (at the left)
213 feet by 43 feet

from
www.alternative-fuels.com/tidal.html

Another 1984 rim turbine example is in Annapolis Royal, Nova Scotia.

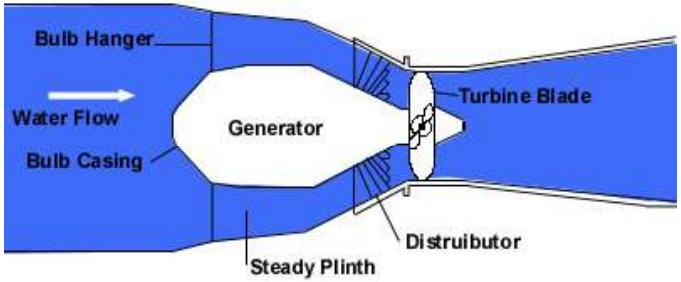
1960s to Present – Dams (Barrages)

- Operates like historical grist mills
- Pro – powerful, reasonably simple
- Con – 15% - 20% capacity factor (outgoing tide only), expensive structure, obstructs navigation, sediment in basin, fish kill (typically rotate 600 - 700 rpm)

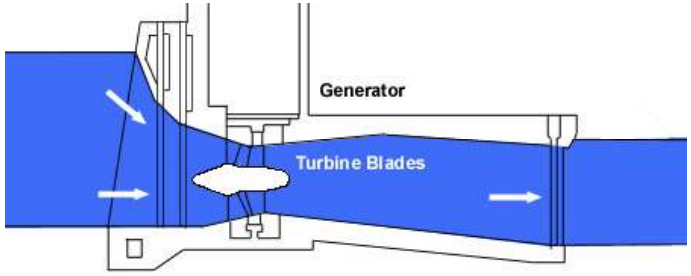


from RESLAB (Australia) website
http://reslab.com.au/resfiles/tidal/text.html

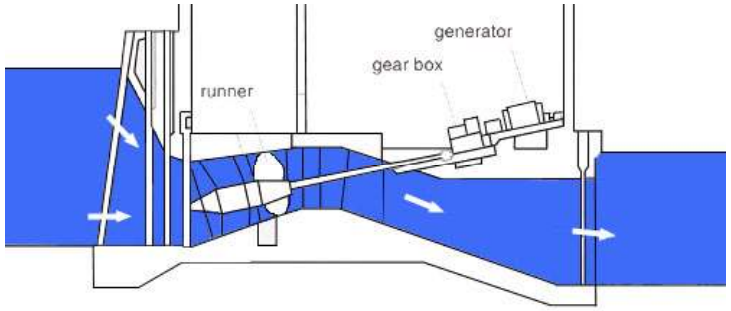
Three turbine technologies used in Dams/Barrages



- Bulb Turbine



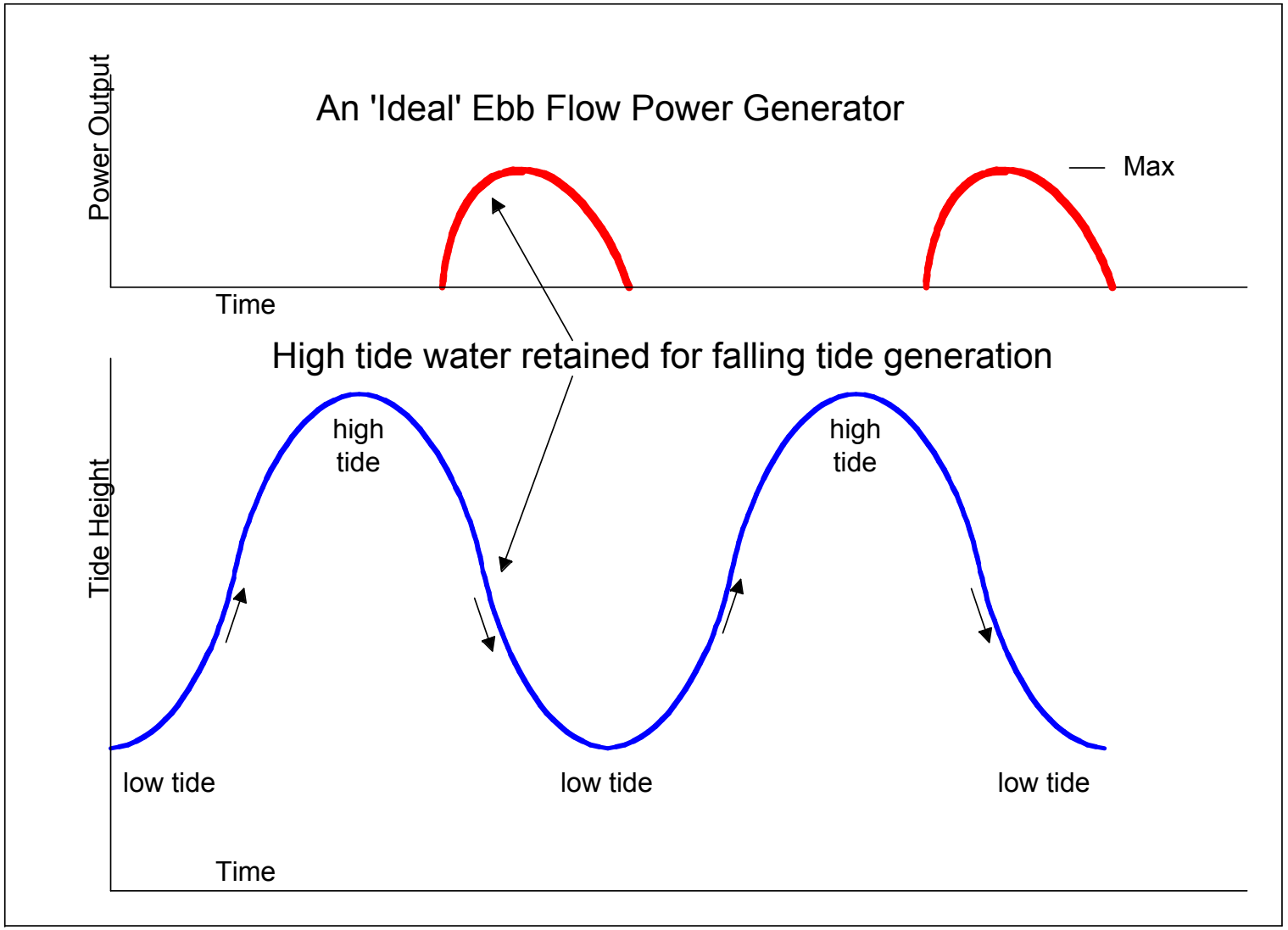
- Rim Turbine



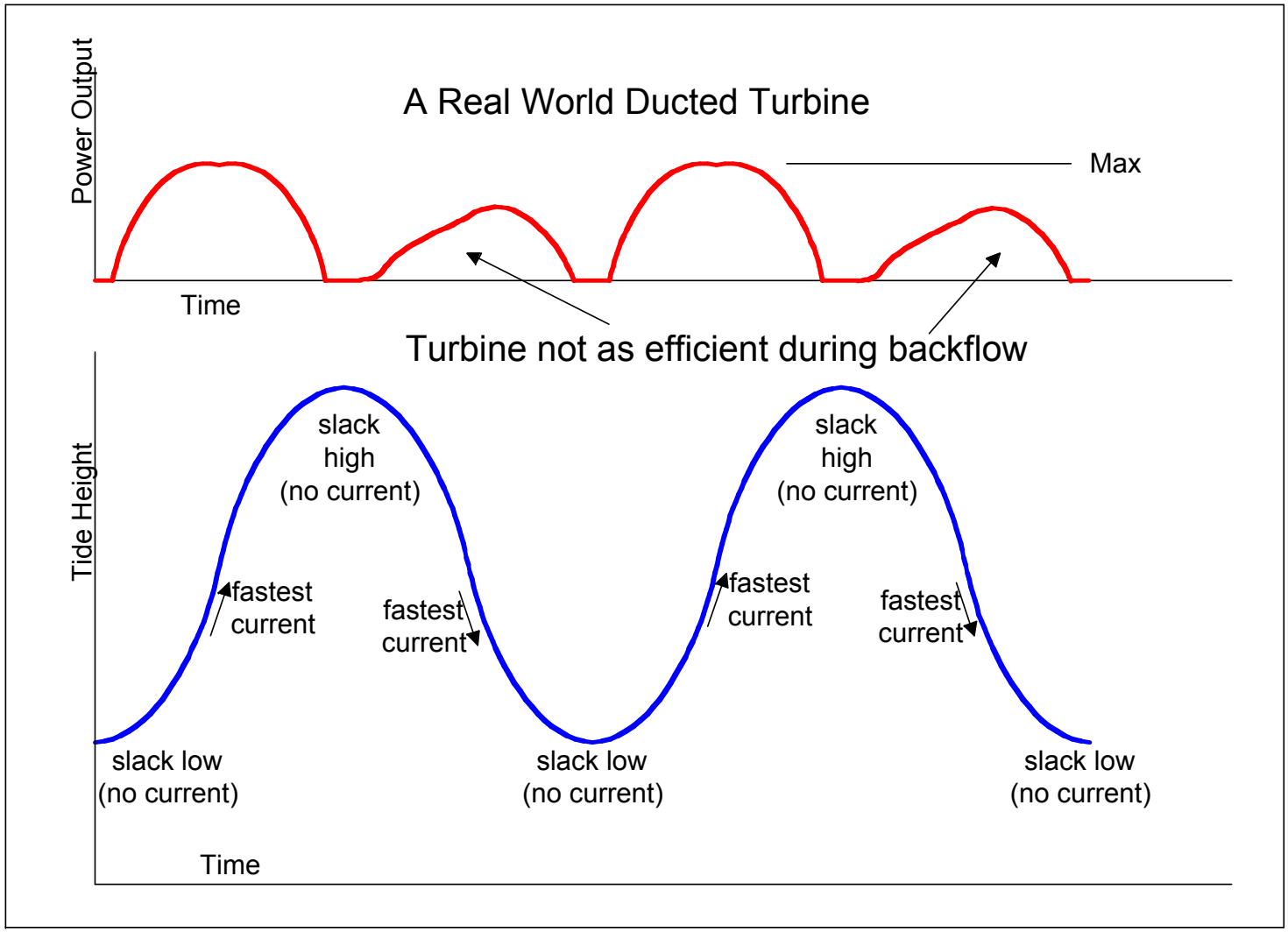
- Tubular (Ducted)Turbine

from RESLAB (Australia) website
http://reslab.com.au/resfiles/tidal/text.html

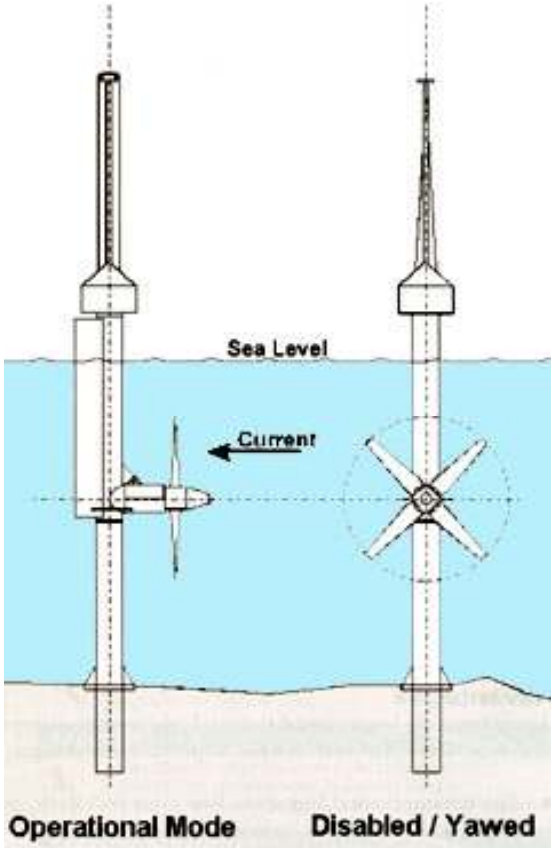
Ebb Flow Power from Barrage



Bi-Directional Ducted Turbine Output



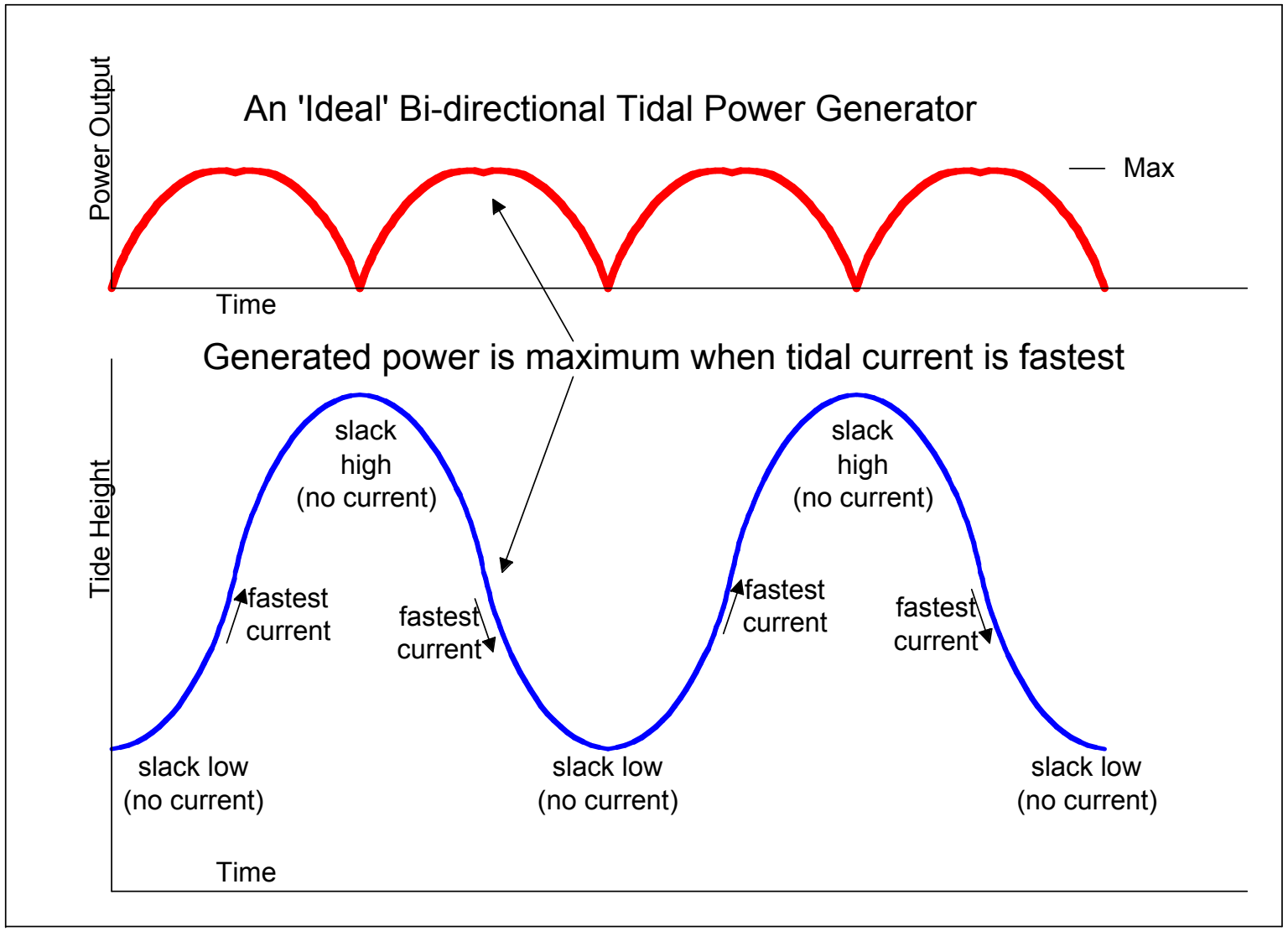
Free Current Tidal Turbines 1990s to Present –



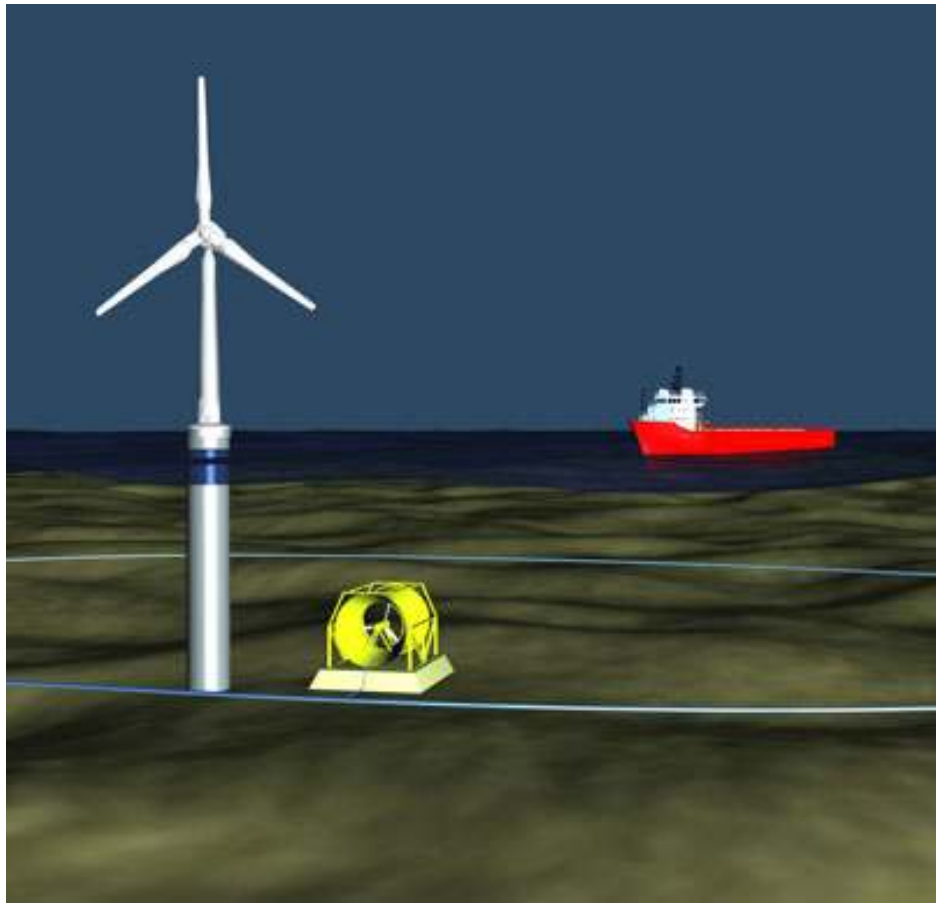
- Underwater Wind Farm with smaller blades and towers sticking out of water
- Pro – less environmental impacts, slow turning
- Con – may obstruct navigation

from RESLAB (Australia) website
http://reslab.com.au/resfiles/tidal/text.html

Bi-Directional Turbine Output



The Power of Water



"Sea water is 832 times denser than air and a non-compressible medium, an 8 knot tidal current is the equivalent of a 390 km/hr wind."

(In other words, 242 miles per hour – the pressure of an F4 tornado.)

Picture from Lunar Energy website
www.lunarenergy.co.uk/environment-benefits-full.htm

Quote from Blue Energy, Canada website
www.BluEnergy.com

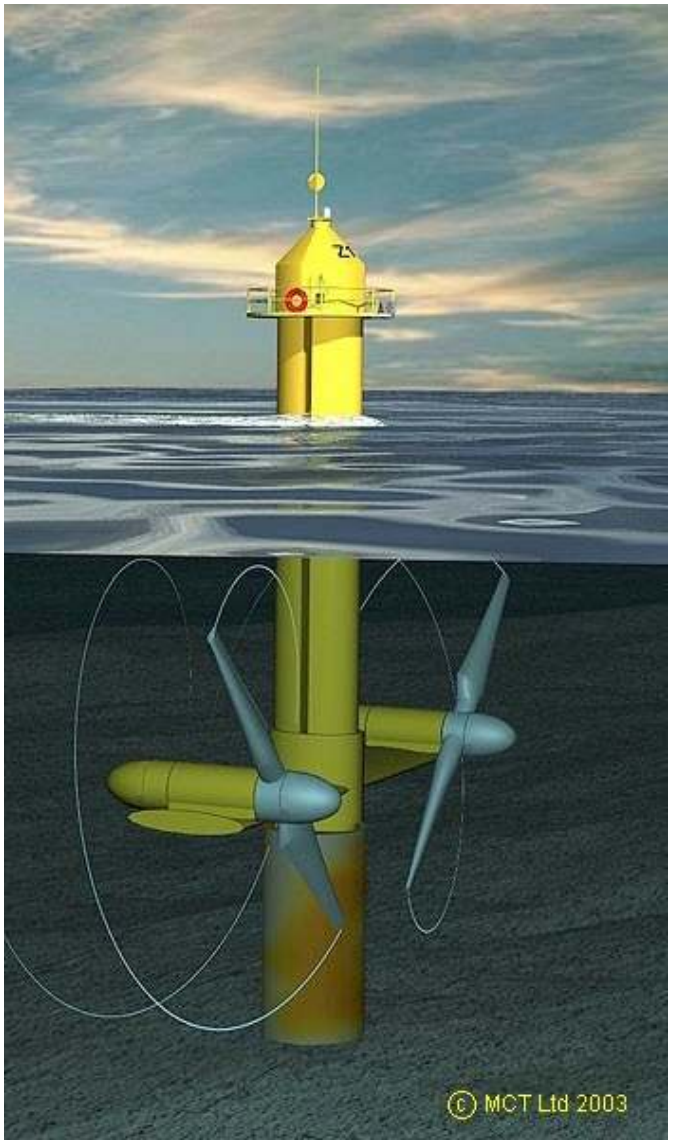
Marine Current Turbine

Devon, UK coast

Operational

- May 2003
- Axial Tower Turbine raised for maintenance.
- Vane at rear causes unit to pivot – capturing both tides

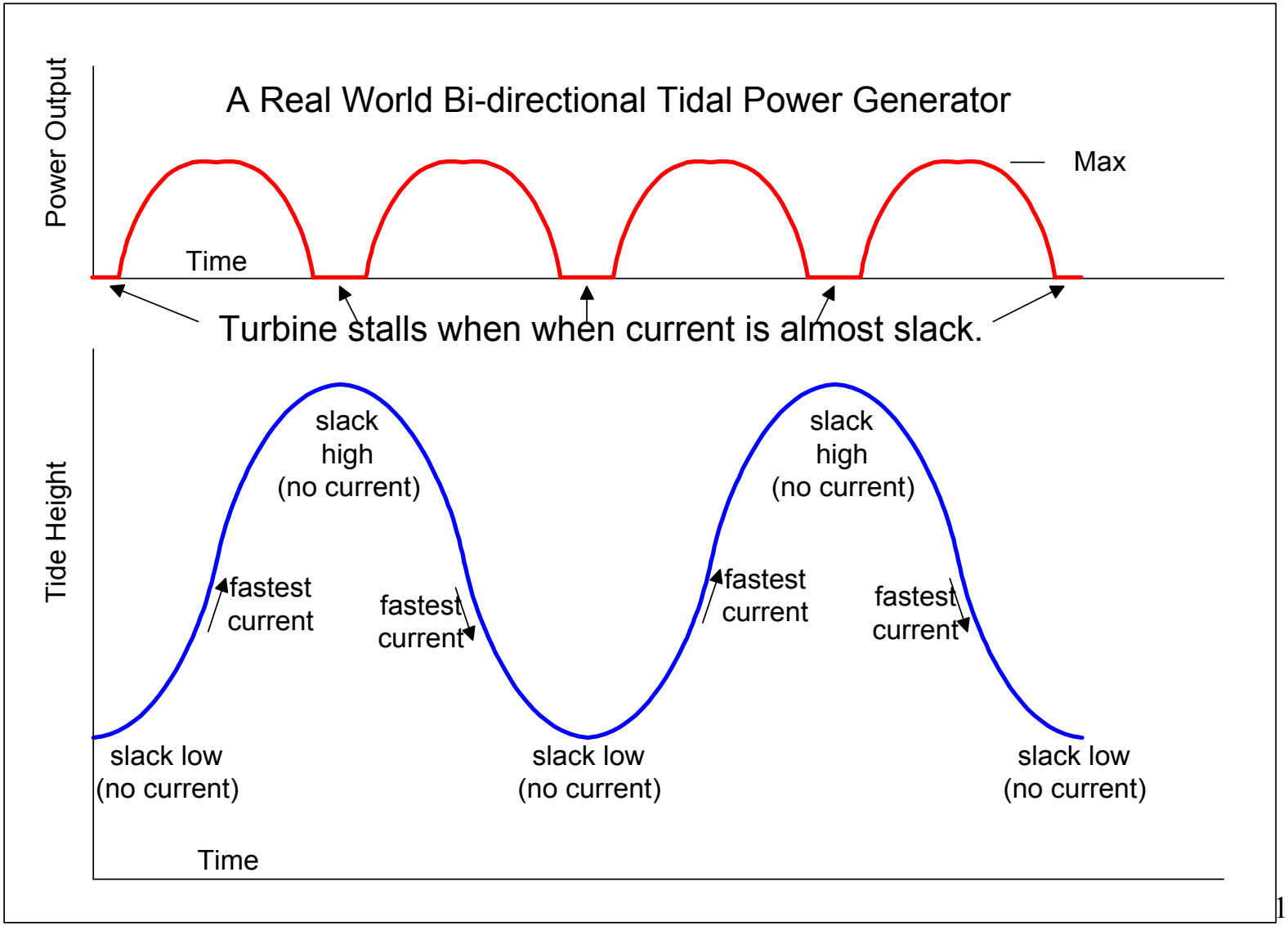
Marine Current Turbine



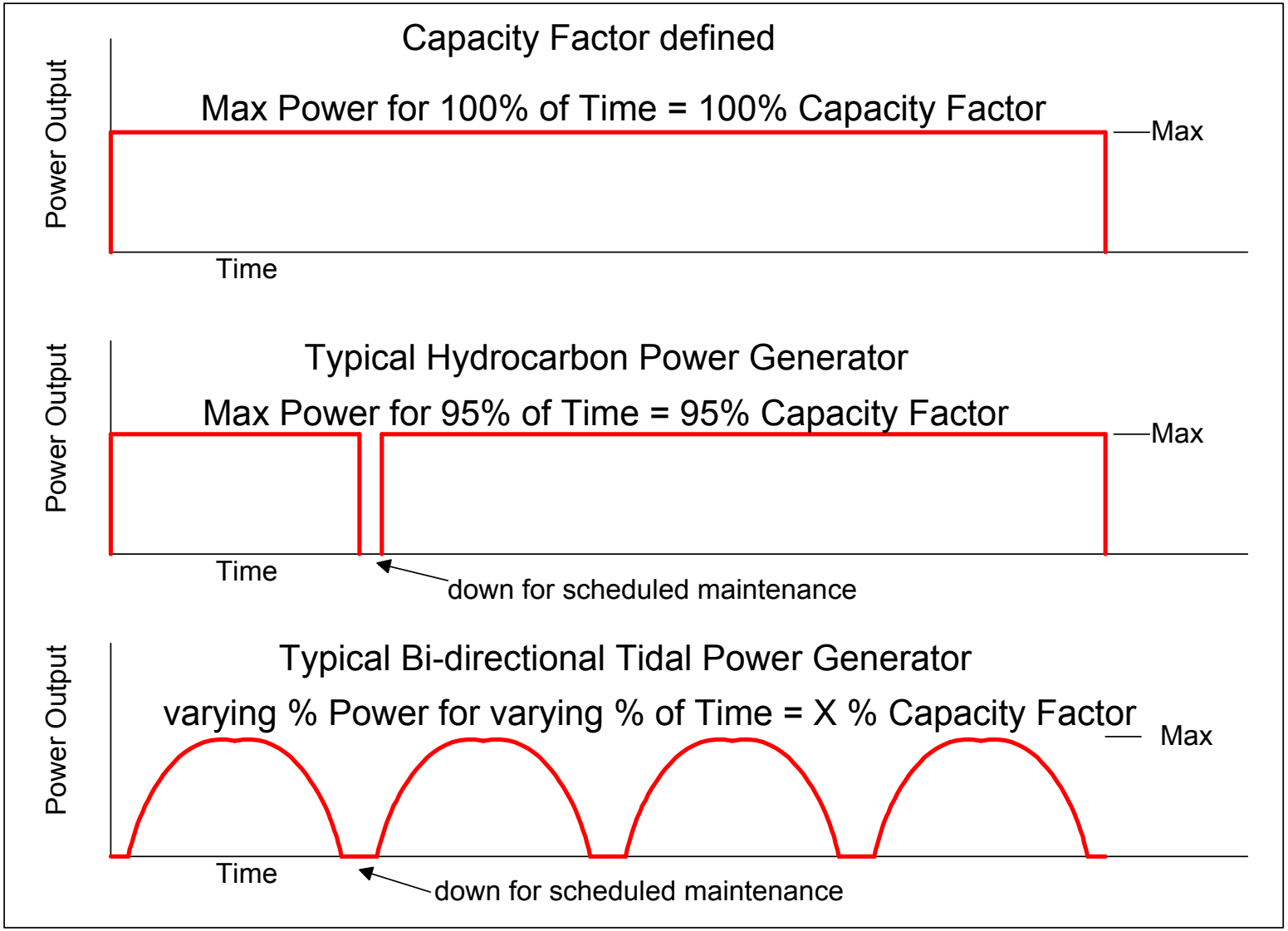
- 1 MW bidirectional version
- Above surface mast reduces servicing costs
- Blades rotate in opposite directions to reduce water pressure interaction

Real World Tidal Turbine Output

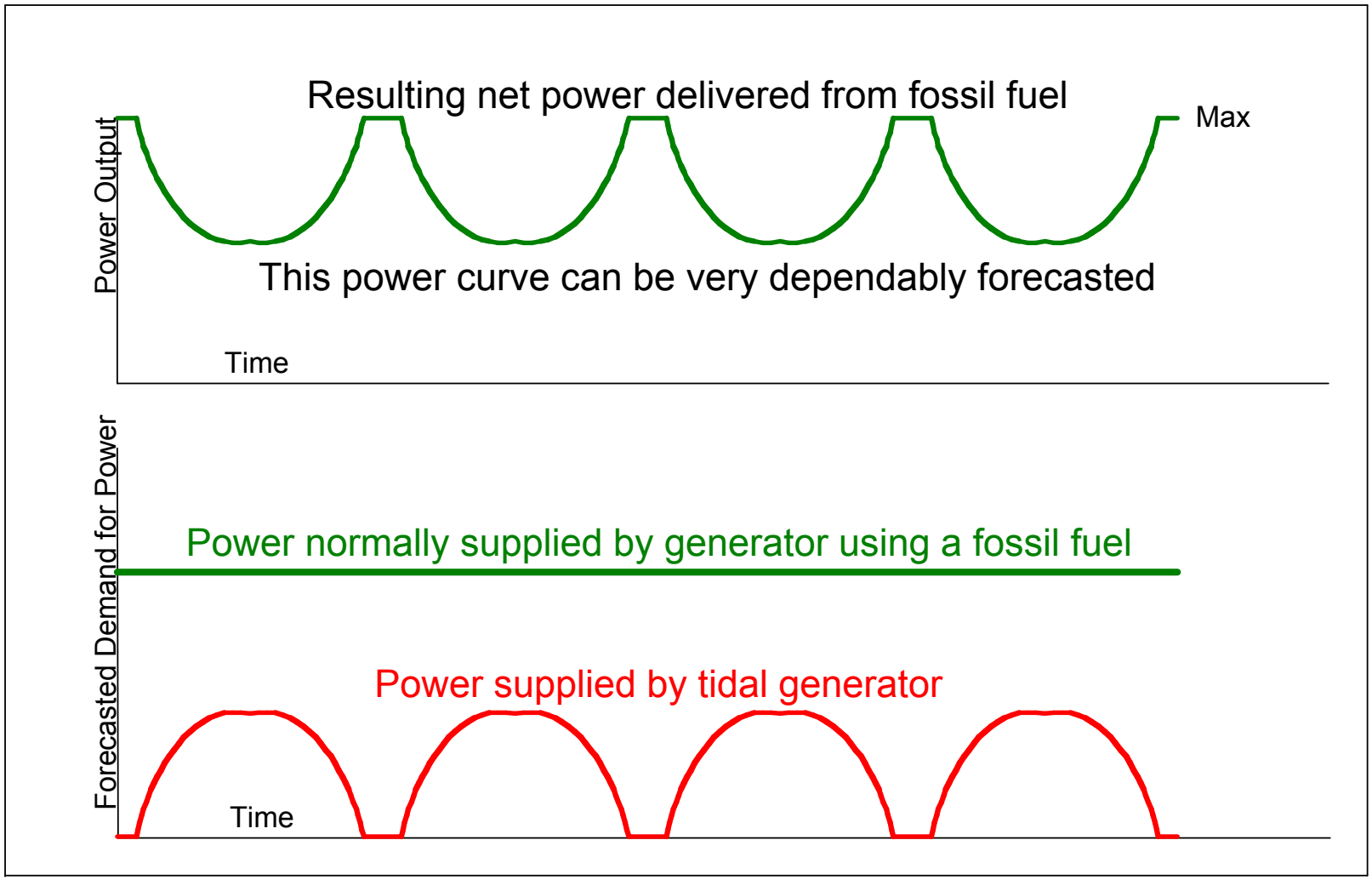
Two-knot "stall point" approx. 1 hour or more in free tidal current



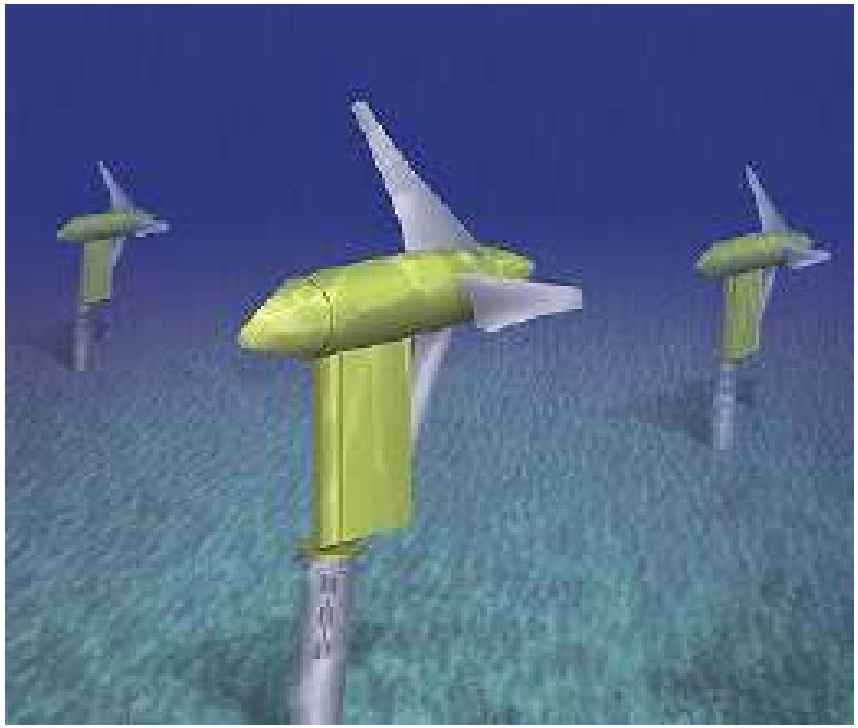
CAPACITY FACTOR



TIDAL - FOSSIL FUEL COMBINATIONS



Bulb Turbines - Verdant Power mid-1990s to Present



- Free-flow underwater windmill (pivoting bottom-mount captures both tides)
- Pro – No dams or fences, 45% Capacity Factor, low environmental impact, does not block navigation, slow turning (32-38 rpm), 7 - 10 cents/kWh in NYC
- Con – Maintenance difficult

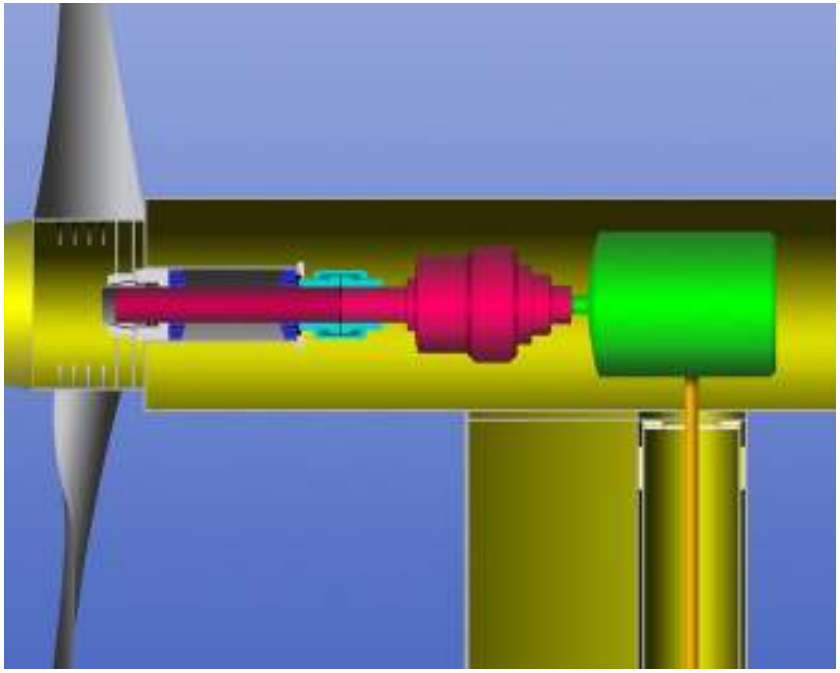
from Verdant Power (USA) website
http://VerdantPower.com

Verdant Power, 2

- Turbine servicing done from special motor barge

from Verdant Power (USA) website
http://VerdantPower.com

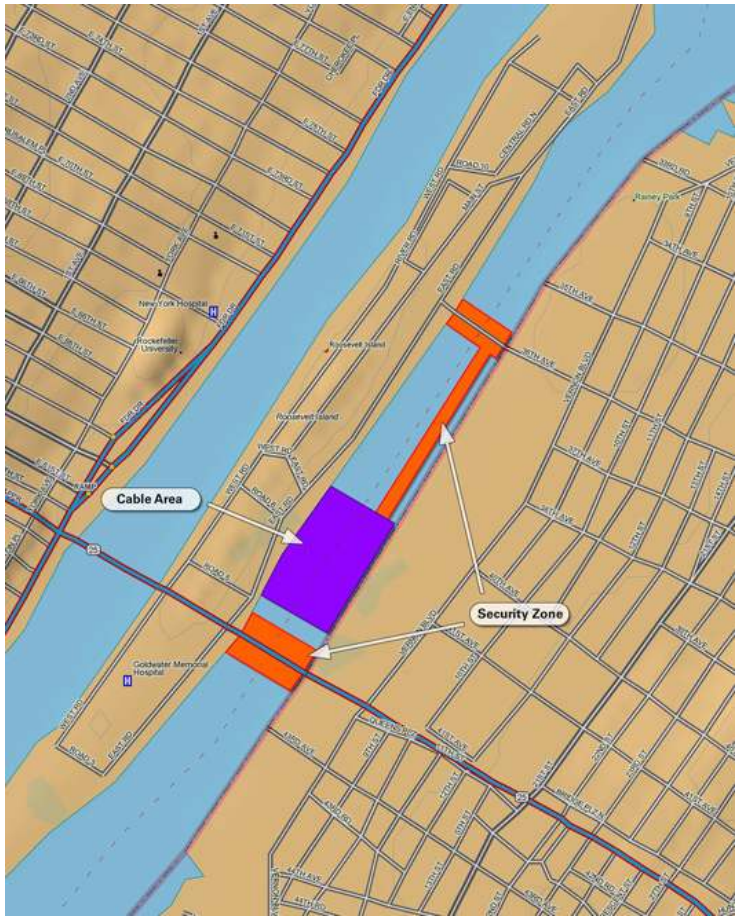
Verdant Power, 3

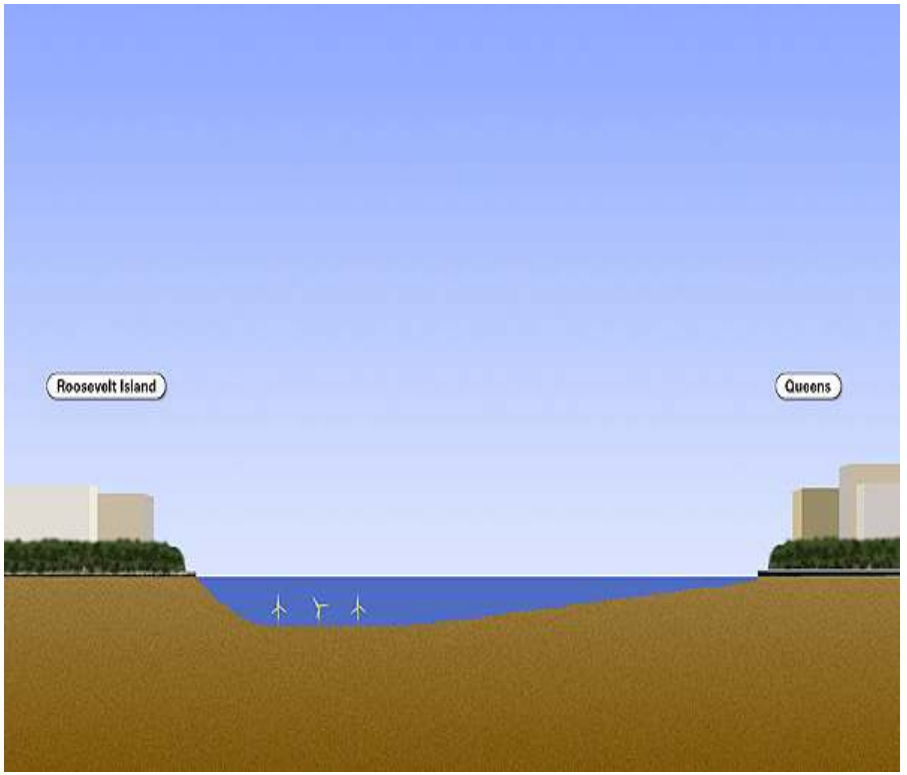


from Verdant Power (USA) website http://VerdantPower.com

Verdant Power, 4

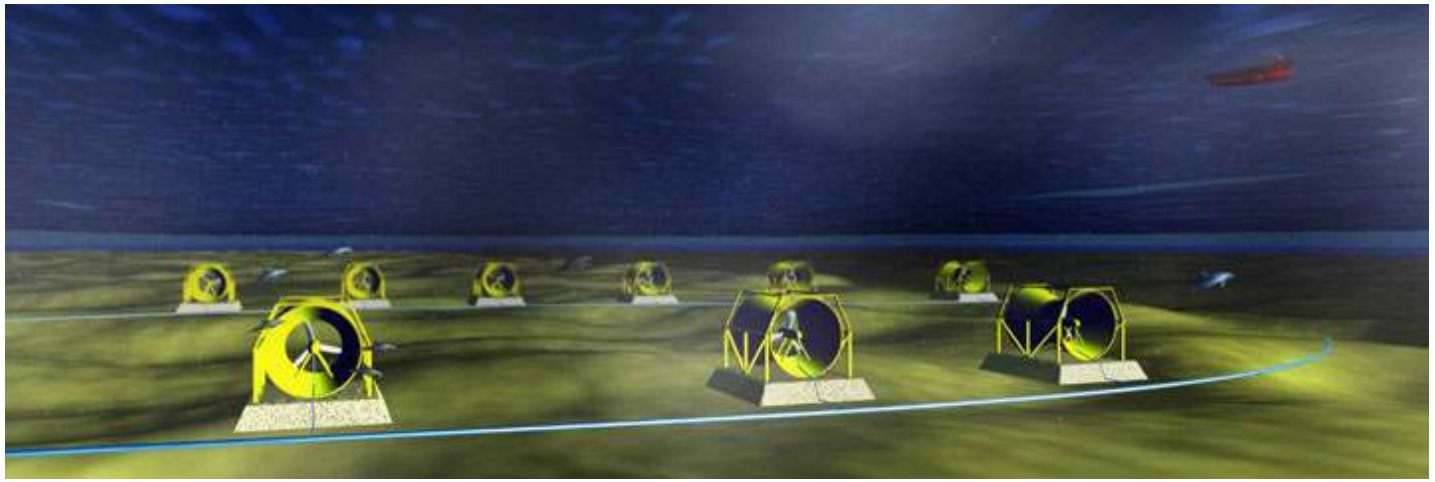
New York's Roosevelt Island Tidal Energy (RITE) Project – 2003 onward

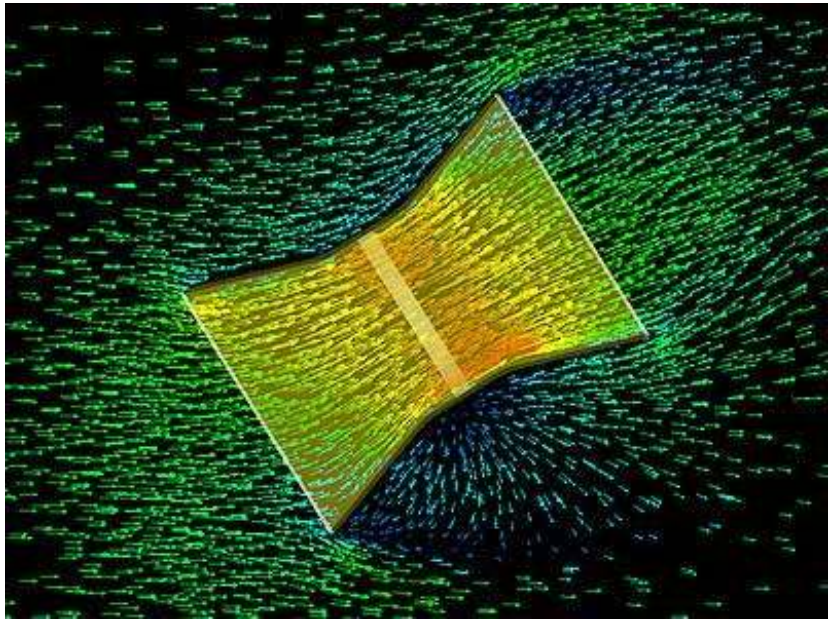




from Verdant Power (USA) website
http://VerdantPower.com

Lunar Energy Ltd, UK





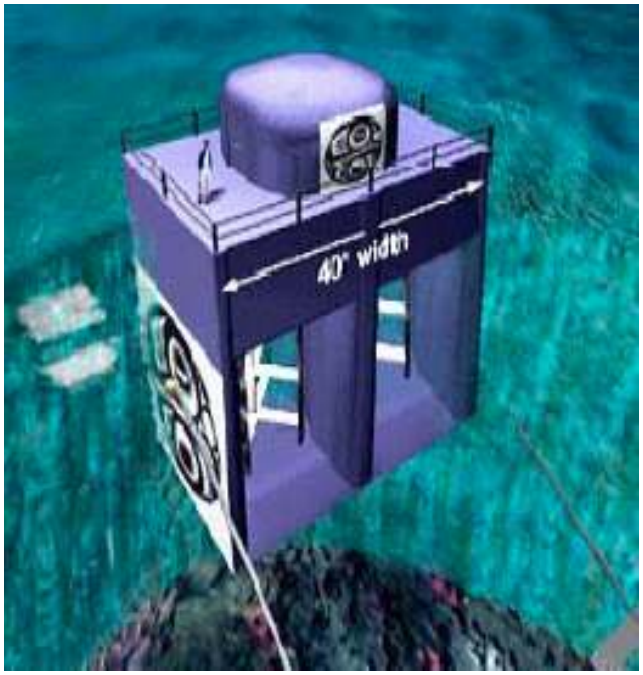
- Venturi-Ducted axial turbine
- Allows 40 degrees off-axis flow
- Ducts reduce interference with nearby turbines

from www.lunarenergy.co.uk

Submerged and Floating ‘Kites’

Underwater Electric Kite twin axial turbines to be anchored to the bottom.

from http://uekus.com



Blue Power twin vertical-axis Davis Turbines in a free-floating array.

from http://www.bluenergy.com/technology.html

These need counter-rotating turbines to cancel torque applied to the generator.

Underwater Electric Kite

- Can be raised or lowered in current - finding greatest velocity
- Housing acts as a venturi duct
- The supporting wires can be modified to shield the turbine from fish, aquatic birds and marine mammals.

from http://uekus.com

The Two Applications to FERC

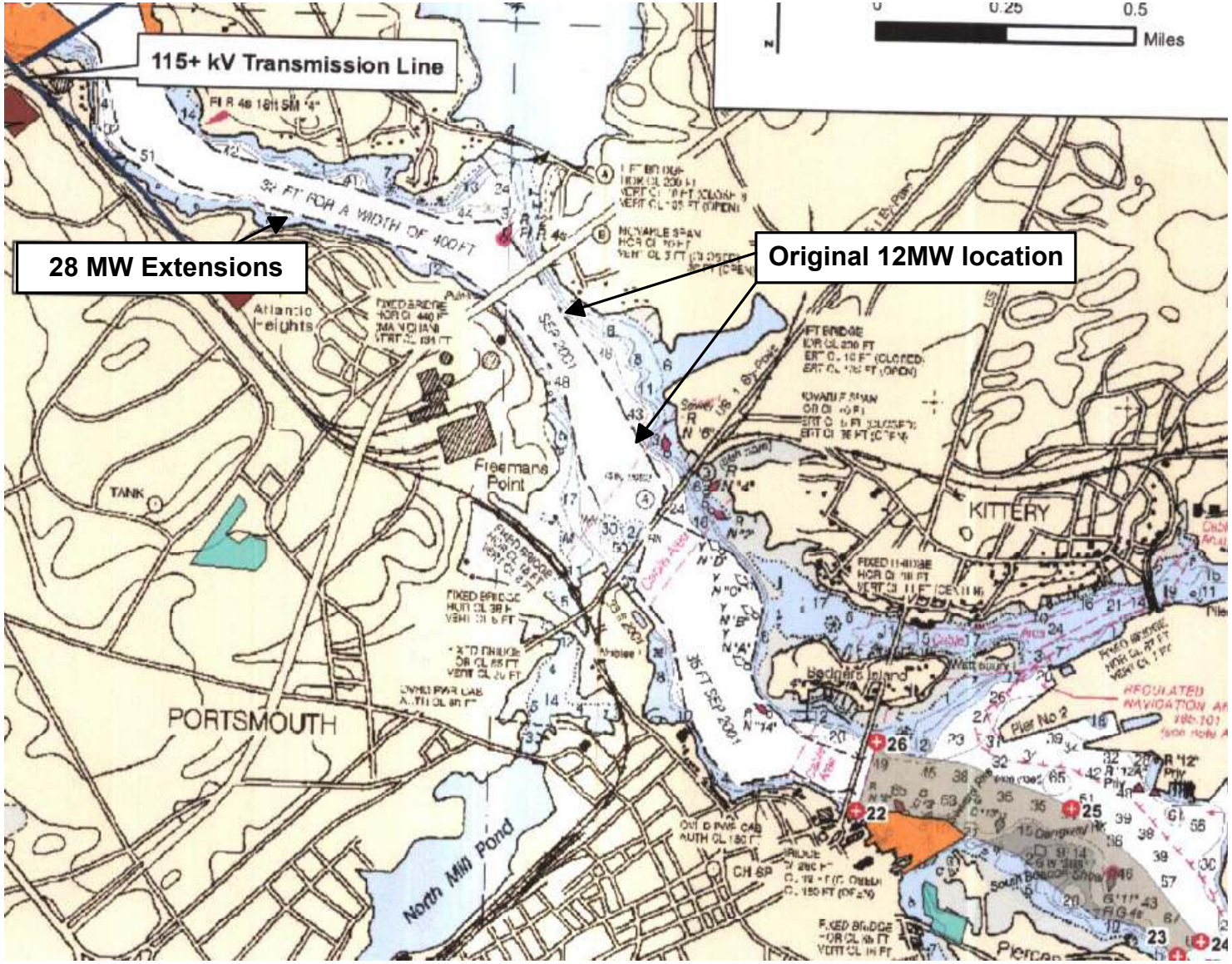
- Underwater Electric Kite Corp.
  - "Competitive" Application July 28, 2006
  - "Piscataqua Tidal Hydrokinetic Energy Project"
  - Two Permit Areas: 12 mW initial, 28 mW follow-on
  - 17 ft. diameter dual turbine units, 336.8 kW
  - 64% Capacity Factor

Source: FERC docket # 12722-000

- New Hampshire Tidal Energy Co.
  - Application March 28, 2006
  - "Portsmouth Area Tidal Energy Project"
  - Four Permit Areas
  - 50 to 100 Tidal In Stream Conversion (TISEC) devices 20 to 50 ft. diameter , 500 kW to 2 mW
  - 80% Capacity Factor (target)

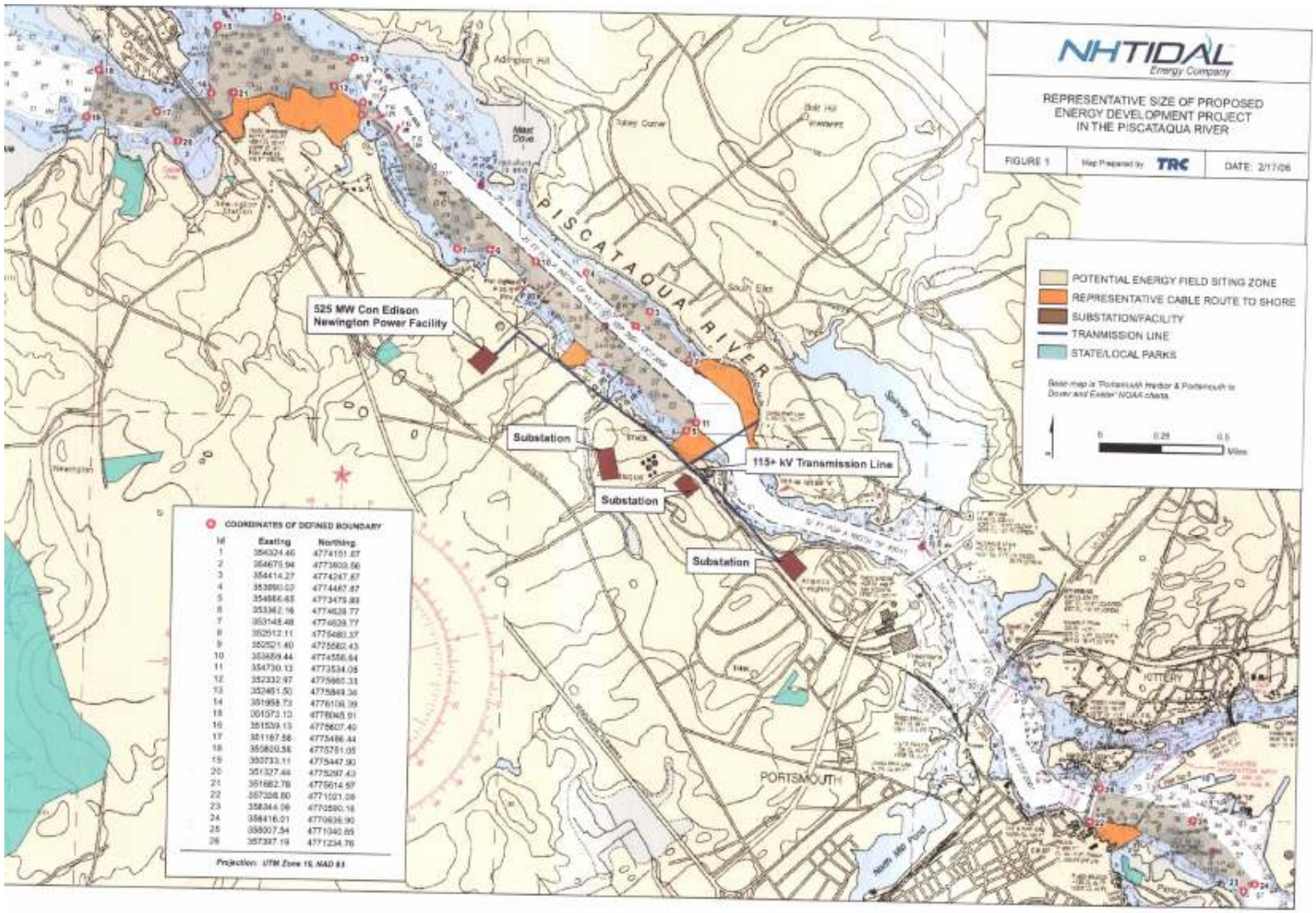
Source: FERC docket # 12264-000

UEK's Two Energy Field Siting Zones



Source: FERC docket # 12722-000 information superimposed onto map from FERC docket # 12264-000

NH Tidal Energy Co.
Four Energy Field Siting Zones



Source: FERC docket # 12264-000

Other Bulb Turbine Variations

Similar features, but hangs from an above structure

from ee.ntu.edu.au/ntcer/projects/tidalpower/main.html

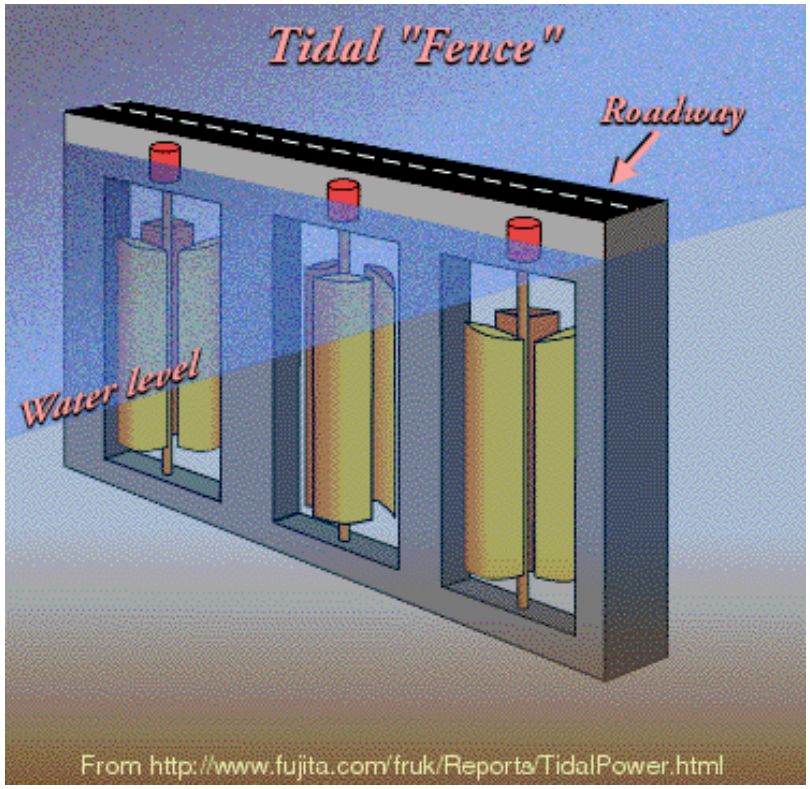
Ganged array of bulb turbines (also used for rim turbines)

from www.hydromatrix.at/

Choke Point Systems

- 8.9 square miles of water (5,696 acres)
- Dropping 7 feet
- Must pass through 23,000 square feet (approx 1/2 acre).

1990s to Present – Tidal Fences (Blue Energy, Canada)



- Can use Cross-Axis Turbines (Daerrieus Turbine a.k.a. Davis Turbine shown) or arrays of bulb or rim axial turbines
- Pro – less costly than dam, Davis Turbine generators above water, no silting, slower turning, 35% - 40% capacity factor (uses both tides)
- Con – Above-water fence structure still expensive to build, obstructs navigation

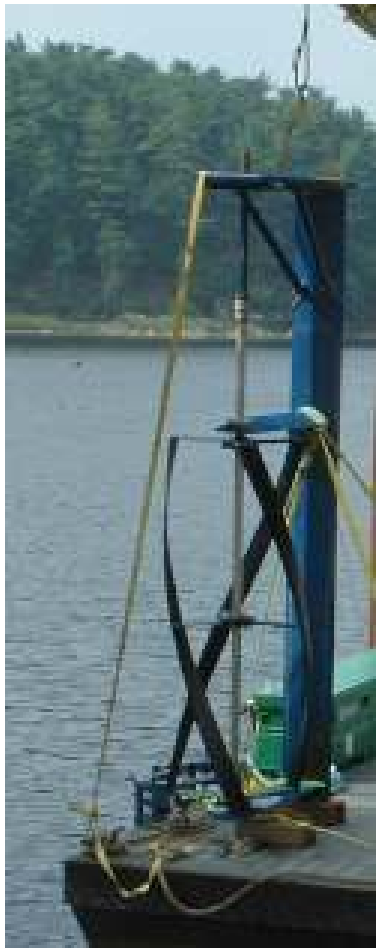
from Fujita Research (Japan) website
www.Fujita.com/archive-frr/TidalPower.html

Darrieus Turbine

Davis water turbine was adapted from Darrieus Turbine (windmill)

from www.bluenergy.com/technology.html

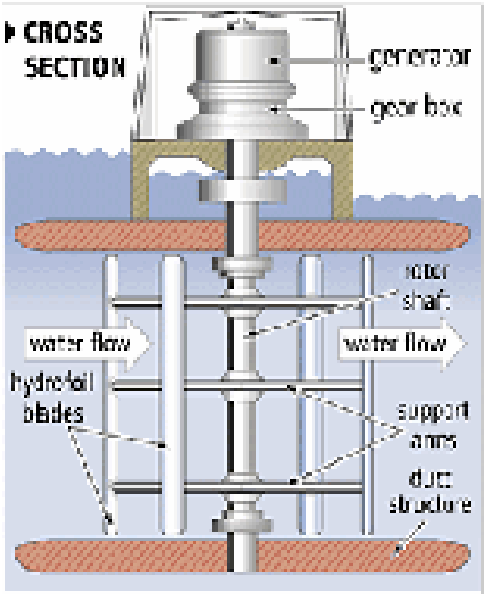
Gorlev Helical Turbine

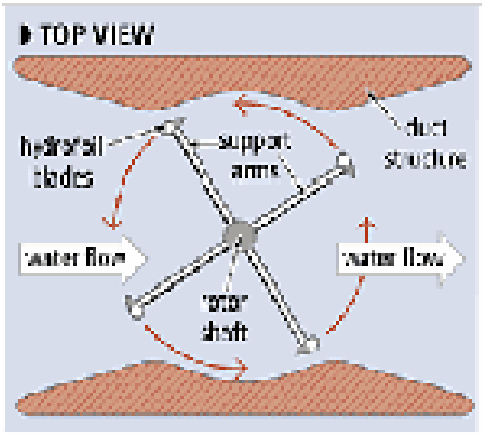


- Horizontal or vertical axis
- Deployed in free stream
- Demonstration project – Merrimack River 2005
- Arrayed turbines interact – cannot closely space

from www.gcktechnology.com/GCK/

Davis Turbine in Tidal Fence

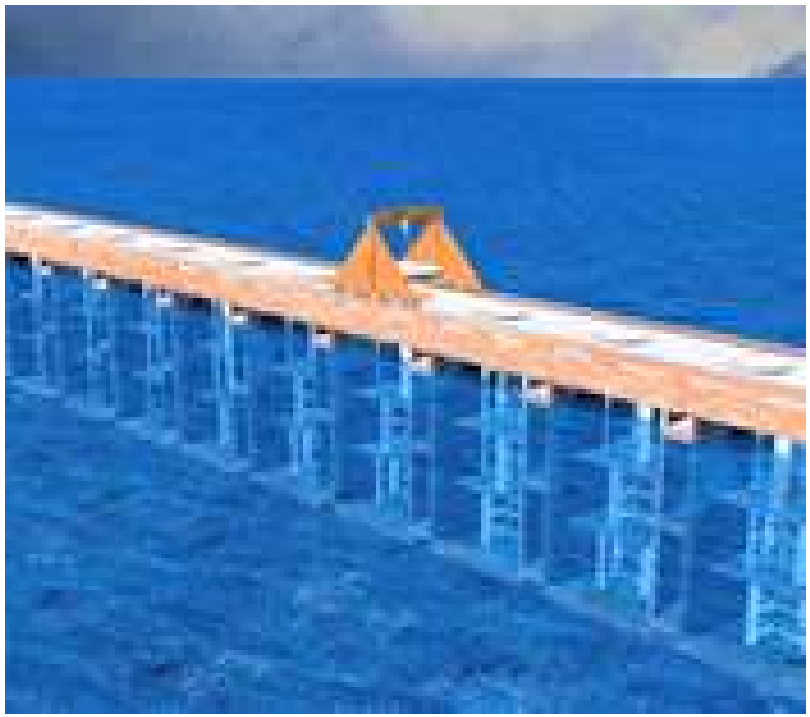




- Vertical cross-axis turbine
- Generator and gearbox above water
- Possible improvement: Add open-air clearance above water surface to avoid ice and debris
- Duct structure eliminates interaction of adjacent turbines

from www.bluenergy.com/technology.html

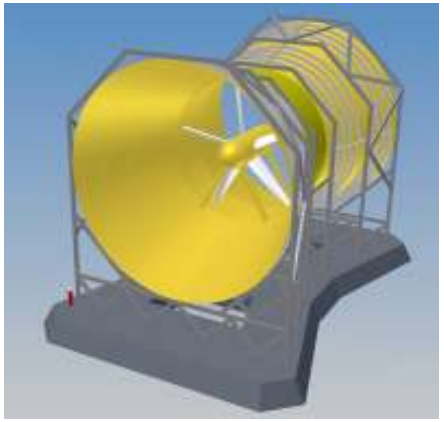
Tidal Fence as Bridge

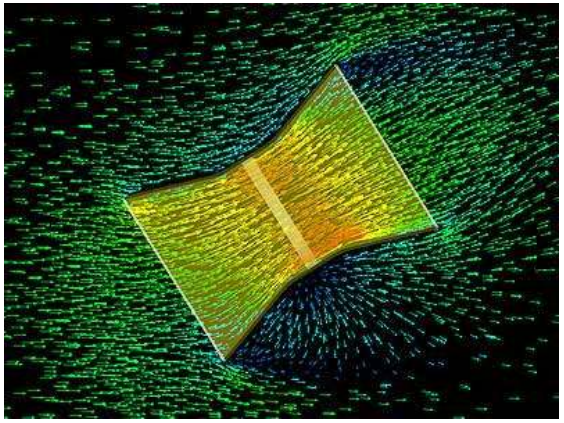


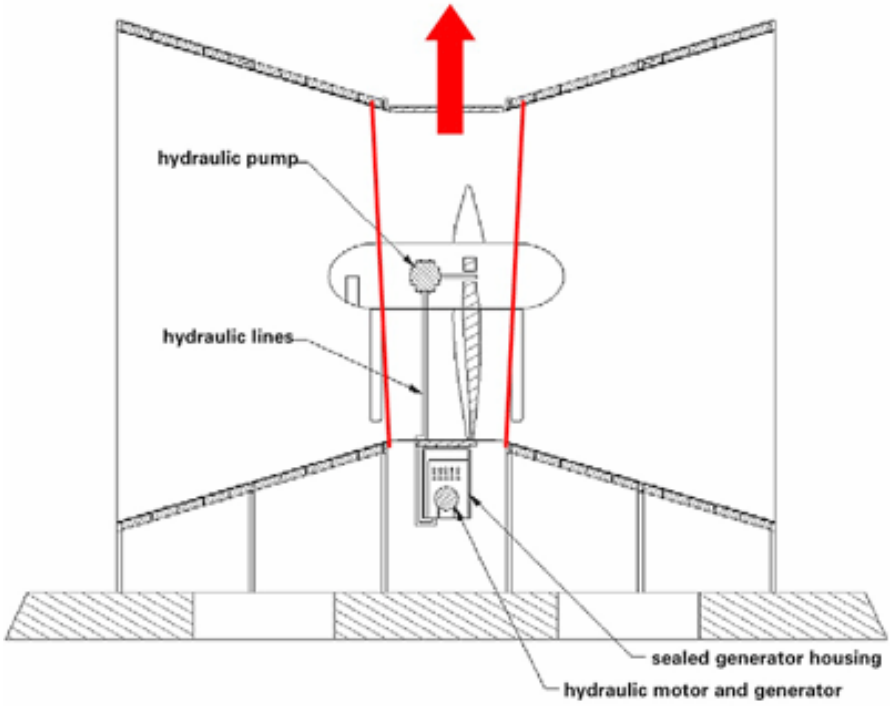
from http://www.bluenergy.com/technology.html

- Proposed by Blue Energy (Canada) for Tacoma Narrows, WA and San Juan Straits, Phillipines
- Proof-of-concept for Detroit-Windsor bridge over Detroit River (summer 2005)
- Pro – avoids most costs of Tidal Fence (co-fund with bridge)
- Con – obstructs navigation, vertical generator linkage may get hit by ice or debris

Lunar Energy Ltd, UK







- Venturi-Ducted axial turbine
- Side-by-side array under a bridge
- Allows 40 degrees off-axis flow
- Ducts reduce interference with nearby turbines
- Multiple hydraulic pumps can be connected into a single generator

from www.lunarenergy.co.uk

HydroVenturi Ltd, UK

Rochester Venturi nozzle operational Derby, England June, 2002

- No moving parts, all concrete
- Sucks in water or air
- Many can be tied into one turbine/generator on shore
- Might be permitted in navigation channels
- Works like venturi hose pump (at left)

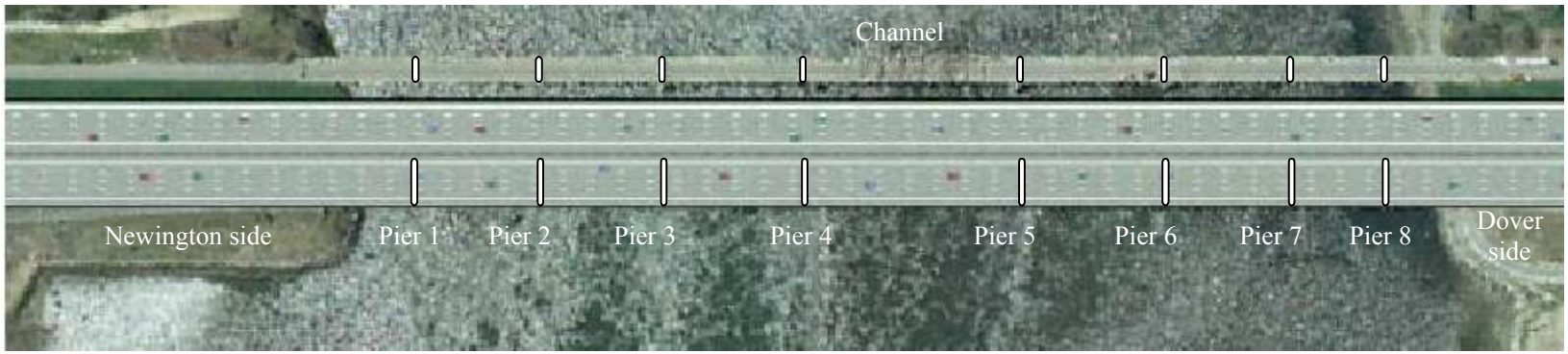
from www.HydroVenturi.com

Little Bay Bridges site

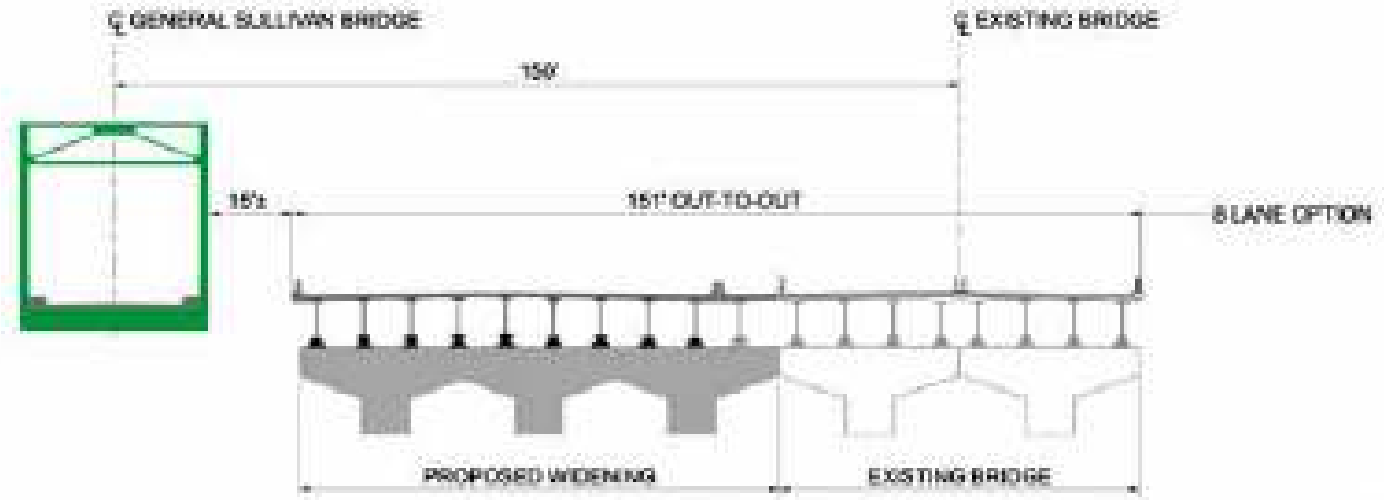
- New bridge to be added between the existing two

http://www.newington-dover.com/images/photo11.jpg

Add New Bridge between Existing

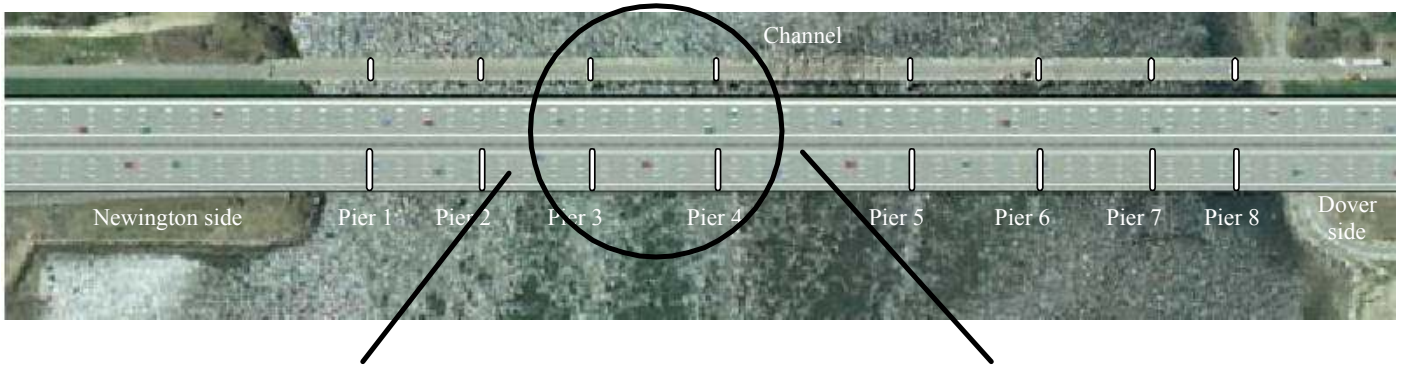


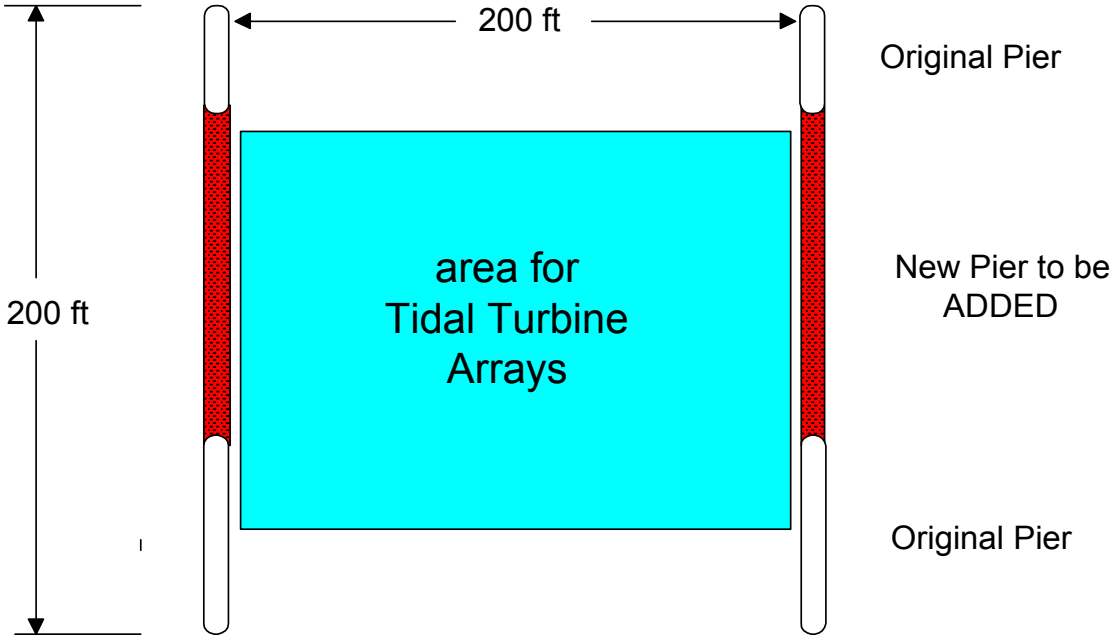
Conceptual Cross-Section
Widen to West Side



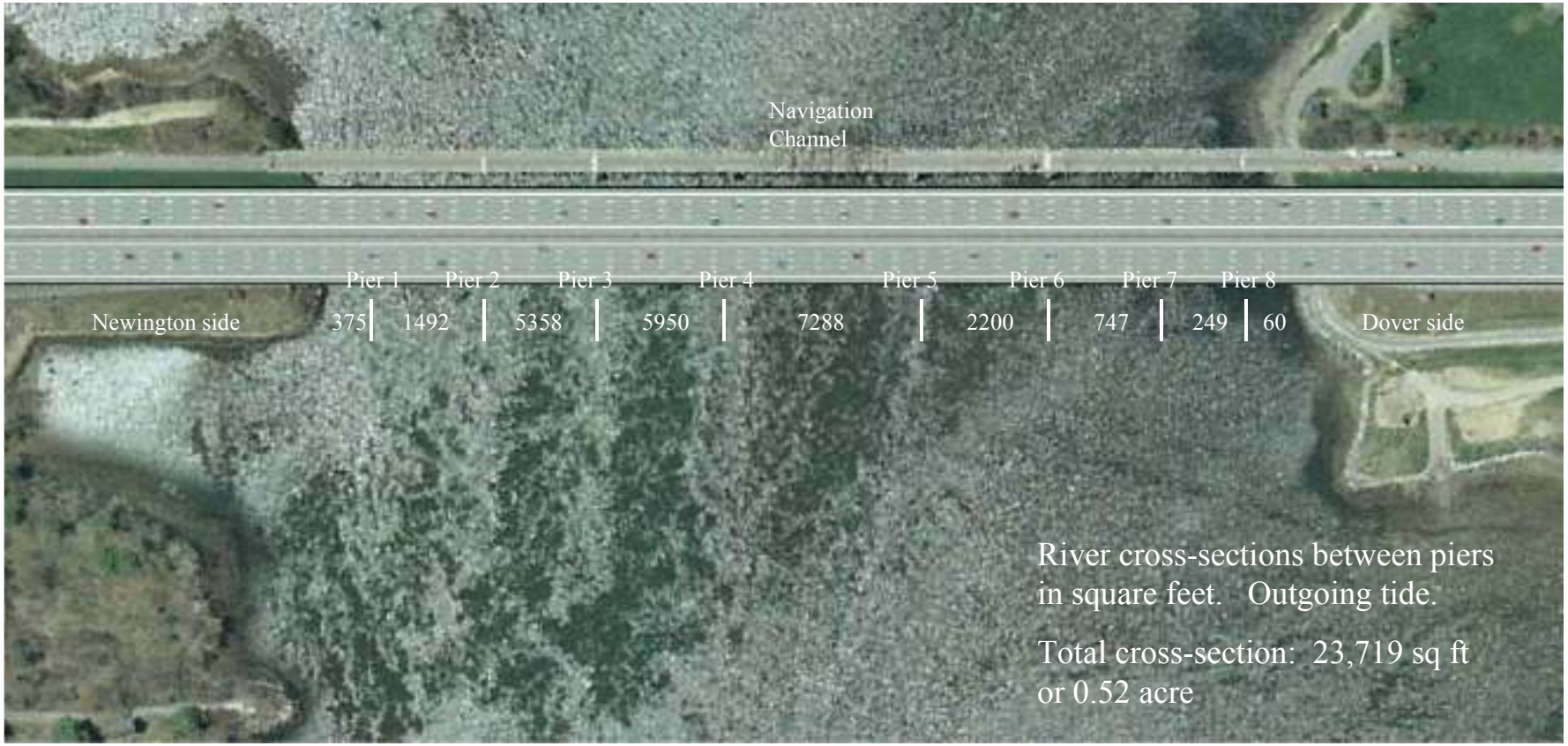
Add New Bridge Between Existing

Individual piers joined together into 200-foot-long ones





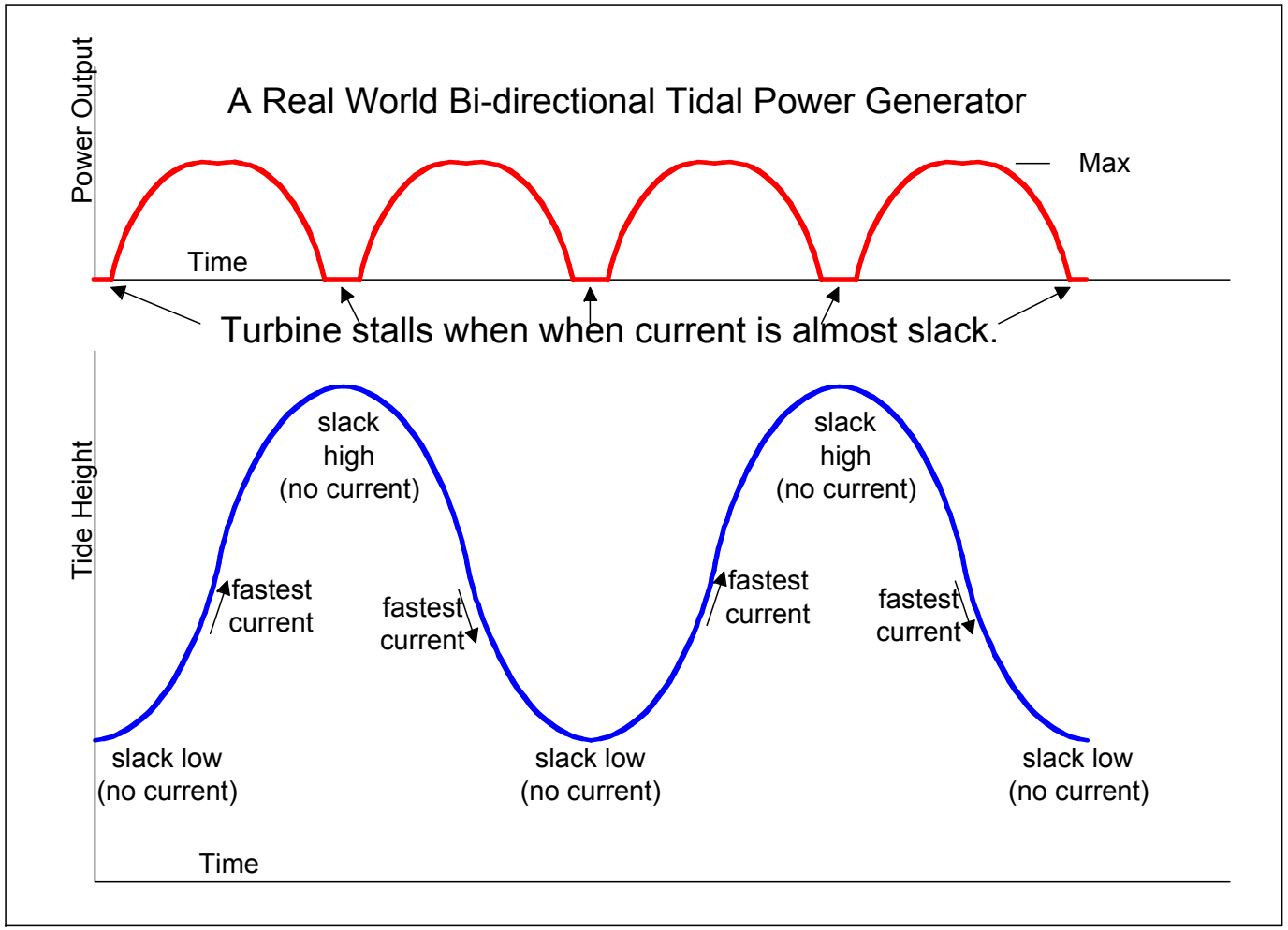
River Cross-Sections



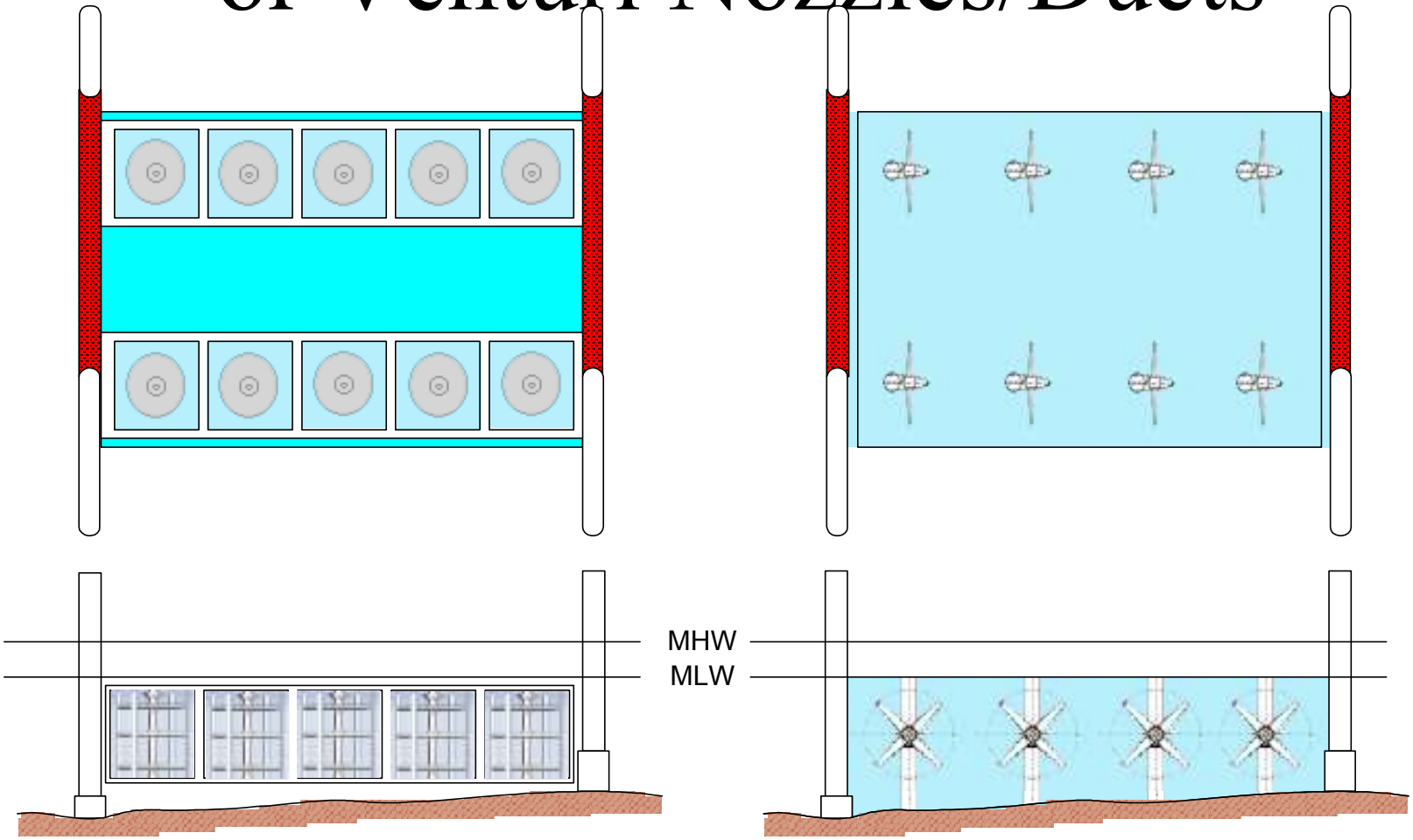
- 8.9 square miles of water (5,696 acres) above bridge
- 1,290 Million Cubic Feet in tidal prism above bridge approximates the river channel volume below bridge
- Must pass through 23,000 square feet (approx 1/2 acre)

Current at Little Bay Bridges

- Two-knot “stall point” is less than 25 minutes
- Zero velocity seldom exceeds 10 minutes
- Can yield a capacity factor of around 60%



Tidal Fences or Turbine Arrays or Venturi Nozzles/Ducts



Tidal Fences

Axial Turbines